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Adansonia digitata; baobab fruit powder; obesity; high-fat diet; lipid profile; blood glucose; liver function; renal biomarkers; cardiac histopathology.

Evaluation of the Anti-Obesity and Metabolic-Modulating Effects of Baobab (*Adansonia digitata* L.) Powder in High-Fat Diet-Induced Obese Experimental Rats

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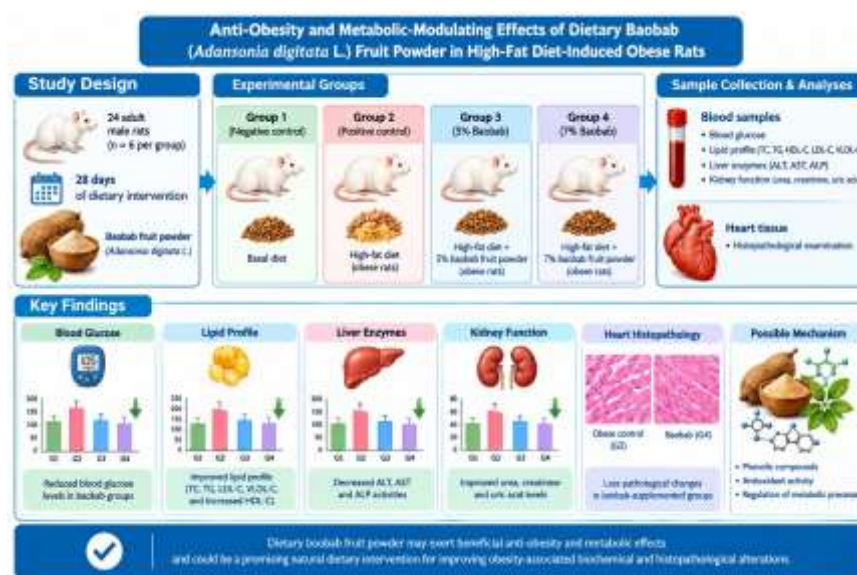
ABSTRACT:

Background: Obesity is associated with metabolic disturbances that may adversely affect lipid and glucose homeostasis and multiple organs. This study evaluated the effects of whole dried baobab (*Adansonia digitata* L.) fruit powder on metabolic, biochemical, and cardiac histopathological parameters in rats with high-fat diet (HFD)-induced obesity.

Methods: Male rats with HFD-induced obesity were allocated to experimental groups receiving dietary supplementation with whole dried baobab fruit powder at 5% or 7% for 28 days. Body-weight gain, serum lipid profile, blood glucose, amylase activity, liver-related biomarkers, renal and hepatobiliary biomarkers, and cardiac histopathology were assessed and compared with untreated control groups.

Results: Baobab supplementation was associated with reduced body-weight gain, with decreases of approximately 10.9% and 26.1% in the 5% and 7% groups, respectively, relative to the obese control group. Triglycerides, total cholesterol, and LDL-C were reduced by approximately 26.9%, 24.3%, and 41.3%, respectively, in the 5% group and by 39.3%, 36.0%, and 67.1% in the 7% group. HDL-C increased from 25.1 mg/dL in the obese control group to 36.5 and 43.8 mg/dL, respectively. Blood glucose and serum amylase were also reduced, particularly at 7%. Favorable changes were observed in ALT, AST, ALP, urea, creatinine, and uric acid, accompanied by improved cardiac histopathological appearance.

Conclusion: Dietary supplementation with whole dried baobab fruit powder was associated with improvements in several metabolic and biochemical abnormalities and with favorable cardiac histopathological changes in HFD-induced obese rats. These findings support the potential of baobab fruit powder as a functional dietary component for mitigating obesity-associated metabolic disturbances. Further studies incorporating longer interventions and mechanistic biomarkers are warranted.



Graphical Abstract. Baobab Fruit Powder Ameliorates Obesity-Associated Metabolic and Cardiac Alterations in HFD-Induced Obese Rats.

1. INTRODUCTION

Obesity is a chronic, multifactorial disease characterized by excessive adiposity that may impair health and is associated with a broad range of metabolic complications. Its prevalence has increased substantially worldwide, making obesity an important global public health concern. According to the World Health Organization (WHO), approximately 890 million adults were living with obesity in 2022, corresponding to about 16% of the global adult population (World Health Organization [WHO], 2025). Obesity is associated with an increased risk of metabolic and cardiovascular disorders, including impaired glucose regulation, dyslipidemia, insulin resistance, and other obesity-related health complications (WHO, 2025). These trends emphasize the need for effective dietary approaches that can complement existing strategies for the prevention and management of obesity. Dietary patterns are important determinants of the development of obesity and its associated metabolic disturbances. Diets characterized by excessive energy density and high fat content can promote increased adiposity and metabolic abnormalities involving glucose and lipid homeostasis. Accordingly, high-fat diet-induced obesity models are widely used in experimental research to investigate the pathophysiological features of obesity and to evaluate the effects of

nutritional and bioactive interventions. Evidence from experimental studies indicates that high-fat diets can produce increases in body weight and adiposity together with alterations in glucose metabolism, lipid profiles, and other metabolic parameters, although the magnitude of these responses depends on factors such as diet composition, duration of feeding, animal strain, and sex (de Moura e Dias et al., 2021). In parallel with increasing interest in nutritional approaches to metabolic health, plant-derived foods have received considerable attention as potential sources of dietary fiber and bioactive compounds. Among these, baobab (*Adansonia digitata* L.) is a nutritionally important African fruit that has attracted scientific interest because of its distinctive nutritional and phytochemical composition. Baobab fruit pulp contains dietary fiber, vitamin C, minerals, organic acids, and various phenolic and flavonoid compounds, including proanthocyanidins and other polyphenols (Kamatou et al., 2011; Silva et al., 2023). The baobab tree (*Adansonia digitata* L.) belongs to the order Malvales, family Malvaceae, and subfamily Bombacoideae. It is a large, long-lived tree native to tropical and southern Africa and parts of the southern Arabian Peninsula. The baobab fruit is characterized by a hard outer shell and a dry, powdery pulp containing numerous seeds. The fruit pulp is nutritionally valuable and contains dietary fiber, minerals, vitamin C, and various bioactive compounds, including polyphenols and other antioxidant constituents (Kamatou et al., 2011; Muthai et al., 2017; Pintão & Moncada, 2023). These constituents have been associated with antioxidant and other biological activities, although their concentrations and biological effects may vary according to geographical origin, fruit maturity, processing conditions, and extraction procedures (Silva et al., 2023). Experimental and human studies have provided preliminary evidence that baobab fruit may influence aspects of glucose and lipid metabolism. In an experimental study, Mohammed et al. (2021) reported that selected baobab fruit pulp extracts improved glucose and lipid-related parameters and reduced oxidative alterations in streptozotocin-induced diabetic rats. In humans, Coe et al. (2013) demonstrated that polyphenol-rich baobab preparations reduced starch digestion and postprandial glycemic responses, supporting the possibility that baobab constituents may influence carbohydrate digestion and glycemic regulation. In addition, Elamin et al. (2019) reported favorable changes in serum lipid parameters in rats fed high-lipid diets supplemented with baobab pulp powder. Despite these findings, the available evidence remains heterogeneous, and much of the experimental literature has investigated extracts, isolated fractions, or specific preparations rather than whole dried fruit consumed as a dietary ingredient. Furthermore, human evidence concerning the cardiometabolic effects of baobab fruit powder remains limited. A recent randomized, placebo-controlled clinical trial protocol was developed to investigate the effects of 16 g/day of baobab fruit powder for 45 days in adults with obesity, highlighting the continuing need for well-controlled human studies (Riedel et al., 2025). Therefore, the present study was designed to evaluate the effects of dietary supplementation with whole dried baobab (*Adansonia digitata* L.) fruit powder in rats with high-fat diet-induced obesity. Specifically, the study investigated the effects of dietary supplementation with 5% and 7% baobab fruit powder for 28 days on body weight, blood glucose, serum lipid profile, liver enzymes, and selected renal and hepatobiliary biomarkers. In addition, cardiac tissue was examined histopathologically to assess potential structural alterations associated with the intervention. The findings may contribute to the experimental evidence regarding the potential role of whole baobab fruit powder as a dietary intervention for modulating metabolic and tissue-level alterations associated with obesity.



Figure 1. Nutritional and phytochemical characteristics of baobab fruit powder (*Adansonia digitata*) and their potential relevance to metabolic health.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Plant Material

Baobab (*Adansonia digitata* L.) fruit was used as the plant material in the present study. The fruits were obtained from a reliable source and processed to obtain dried fruit powder suitable for dietary supplementation. *Adansonia digitata* is recognized as a nutritionally and phytochemically important plant, and its fruit contains several bioactive constituents, including phenolic compounds and other potentially bioactive metabolites (Silva et al., 2023). The dried baobab fruit material was used directly in powdered form and incorporated into the experimental diets at concentrations of 5% and 7%. No solvent extraction was performed.

2.1.2. Experimental Animals

Twenty-four adult male Sprague–Dawley albino rats, weighing approximately 150 ± 10 g, were obtained from the Agricultural Research Center, Egypt. The animals were housed under controlled laboratory conditions and were randomly allocated to four experimental groups, with six rats per group ($n = 6$). The experimental design and reporting of the animal study were conducted with consideration of established recommendations for transparent reporting of in vivo animal research, including specification of animal characteristics, experimental groups, interventions, and outcome measures (Percie du Sert et al., 2020).

2.1.3. Dietary Ingredients and Chemicals

The basal and experimental diets were prepared using standard dietary ingredients, including casein, corn oil, cellulose, sucrose, corn starch, mineral and vitamin mixtures, and choline chloride. The high-fat diet (HFD) used for obesity induction was prepared according to the same formulation used in the preceding experimental protocol. All chemicals and reagents used for biochemical analyses were of analytical grade or were obtained as commercial diagnostic kits from appropriate suppliers. Analytical procedures for food and plant materials were selected according to established standard analytical principles, including those described by AOAC INTERNATIONAL (AOAC International, 2016).

2.2. Preparation of Baobab Fruit Powder

The baobab fruits were carefully cleaned to remove adhering impurities and foreign materials. The edible fruit material was dried under appropriate conditions until a stable dry weight was obtained and then finely ground to produce a homogeneous powder. The prepared powder was stored in clean, airtight containers under conditions that minimized exposure to moisture, heat, and light until use. The entire dried fruit material was used as a powder without solvent extraction or fractionation. This approach was selected to evaluate the dietary effect of baobab fruit in a form closer to its conventional food use, rather than evaluating an isolated extract. The presence of phenolic and other bioactive constituents in baobab fruit has been documented in recent phytochemical reviews (Silva et al., 2023).

2.3. Experimental Animals and Housing Conditions

The animals were allowed to acclimatize to the laboratory environment before initiation of the experimental procedures. Rats were housed in clean, well-ventilated cages under standardized environmental conditions, including a 12-h light/12-h dark cycle, an ambient temperature of approximately $22 \pm 2^\circ\text{C}$, and relative humidity of approximately 50–60%. The animals had free access to drinking water throughout the study. Animal housing, allocation, intervention, and sample collection procedures were conducted in accordance with institutional requirements for laboratory animal research and the principles of appropriate reporting of animal experiments (Percie du Sert et al., 2020).

2.4. Induction of Experimental Obesity

Experimental obesity was induced before the beginning of the 28-day treatment period. The animals assigned to the obese groups were fed the high-fat diet using the same dietary composition and preparation protocol adopted in the previous experimental study. The HFD was administered for the established obesity-induction period before the initiation of baobab supplementation. Development of the obese phenotype was assessed by monitoring body-weight changes and according to the criteria adopted in the experimental protocol. High-fat feeding is widely used to induce obesity-associated metabolic disturbances in laboratory rodents and to investigate potential dietary interventions targeting body weight and metabolic

health (Lee et al., 2023). Following successful induction of obesity, the obese animals were assigned to the positive-control and baobab-supplemented groups.

2.5. Experimental Design and Dietary Treatment

After induction of obesity, the animals were divided into four experimental groups, with six rats in each group ($n = 6$), as follows:

Group 1 – Negative control: Non-obese rats receiving the basal diet without baobab supplementation.

Group 2 – Positive control: Obese rats receiving the high-fat diet without baobab supplementation.

Group 3 – 5% baobab: Obese rats receiving the experimental diet supplemented with 5% baobab fruit powder.

Group 4 – 7% baobab: Obese rats receiving the experimental diet supplemented with 7% baobab fruit powder. The dietary intervention continued for 28 consecutive days. Food intake and body weight were recorded throughout the treatment period.

The use of a non-obese control, an obese untreated control, and treatment groups receiving defined dietary concentrations allows the effects associated with baobab supplementation to be evaluated against both normal and obesity-associated metabolic conditions. Such experimental group definition is consistent with recommendations for clear reporting of animal allocation and interventions (Percie du Sert et al., 2020).

2.6. Composition of the Experimental Diets

The experimental diets were prepared according to the dietary formulation used in the previous experimental protocol, with the required modification for incorporation of baobab fruit powder at 5% and 7%. The high-fat diet used for obesity induction retained the same ingredient composition and proportions as those established in the previous protocol. For the treatment diets, baobab fruit powder was incorporated into the diet at the required concentration on a weight/weight basis. The dietary components were thoroughly mixed to obtain a homogeneous preparation and to ensure consistent distribution of the baobab powder throughout the diet.

2.7. Proximate Chemical Analysis

The baobab fruit powder was subjected to proximate chemical analysis to determine its major nutritional components. Moisture, ash, crude protein, and crude lipid contents were determined using recognized analytical procedures. Standardized analytical approaches such as those compiled by AOAC INTERNATIONAL are widely used for the chemical characterization of food and botanical materials (AOAC International, 2016). AOAC emphasizes the use of standardized and scientifically evaluated analytical methods to improve the reliability and reproducibility of chemical measurements. Where applicable, analyses were performed in replicate, and the results were expressed using the appropriate units and basis of calculation.

2.8. Determination of Phenolic Compounds by HPLC

The phenolic profile of the baobab fruit powder was determined using high-performance liquid chromatography (HPLC) according to the same chromatographic procedure and instrumental conditions used in the previous experimental study. The analysis was performed using an Agilent Technologies 1260 Infinity II HPLC system equipped with a diode-array detector and an autosampler. Chromatographic separation was carried out using an Eclipse XDB-C18 column (150×4.6 mm, 5 μ m particle size). The mobile phase consisted of acetonitrile and 2% aqueous acetic acid and was delivered according to the previously established gradient program. The flow rate, injection volume, chromatographic run time, and detection wavelengths were maintained according to the validated laboratory procedure used in the previous experiment. Baobab samples were prepared and filtered before chromatographic analysis. Individual phenolic compounds were identified by comparison of their retention times and spectral characteristics with those of authentic reference standards analyzed under the same chromatographic conditions. Quantification was performed using calibration curves prepared from the corresponding standards. The use of chromatographic analysis for characterization of baobab phytochemicals is supported by previous research demonstrating the presence of diverse bioactive compounds in *A. digitata* fruit (Mohammed et al., 2021;

Silva et al., 2023). Mohammed et al. (2021) identified numerous metabolites in baobab fruit pulp using advanced chromatographic and mass-spectrometric approaches, further supporting the phytochemical complexity of the fruit.

2.9. Blood Collection and Tissue Processing

At the end of the 28-day treatment period, the rats were fasted overnight before blood collection. Blood samples were collected using the approved experimental procedure and allowed to clot. The samples were then centrifuged to separate the serum. The resulting serum samples were transferred into appropriately labeled tubes and stored at -20°C until biochemical analyses were performed. Following blood collection, the animals were euthanized according to the approved experimental procedure. Heart tissues were carefully removed, examined macroscopically, and representative specimens were collected for histopathological examination. Tissue samples were fixed in 10% neutral buffered formalin until further processing.

2.10. Biochemical Analyses

Serum biochemical parameters were determined using standard enzymatic and colorimetric procedures and appropriate commercial diagnostic kits according to the manufacturers' instructions. The selected biochemical parameters were intended to characterize alterations in glucose metabolism, lipid metabolism, hepatic function, and renal function associated with experimental obesity and dietary intervention.

2.10.1. Blood Glucose: Serum glucose concentration was determined using a validated enzymatic colorimetric method and an appropriate commercial diagnostic kit.

2.10.2. Lipid Profile: The serum lipid profile included total cholesterol (TC), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C). Low-density lipoprotein cholesterol (LDL-C) and very-low-density lipoprotein cholesterol (VLDL-C) were calculated where appropriate using established equations. When applicable, LDL-C was estimated using the Friedewald equation (Friedewald et al., 1972).

2.10.3. Liver Function Parameters: Liver function was assessed by measuring serum activities of alanine aminotransferase (ALT) and aspartate aminotransferase (AST), together with the other liver-related biochemical parameters included in the study. The assessment of hepatic biochemical parameters is particularly relevant in experimental obesity because high-fat feeding can be associated with metabolic and hepatic alterations. Previous experimental research has also demonstrated that dietary and metabolic interventions can influence biochemical and pathological outcomes in animal models (Mohammed et al., 2021).

2.10.4. Kidney Function Parameters : Renal function was evaluated by measuring serum urea and uric acid concentrations using standard biochemical procedures and commercial diagnostic kits according to the manufacturers' instructions.

2.11. Histopathological Examination

Heart tissue specimens were processed using routine histopathological procedures. The fixed tissues were dehydrated through graded concentrations of ethanol, cleared using an appropriate clearing agent, embedded in paraffin wax, sectioned, and stained with hematoxylin and eosin (H&E). The stained sections were examined microscopically to identify structural alterations in the cardiac tissue and to evaluate possible differences among the experimental groups. Histopathological assessment was included as a complementary endpoint to the biochemical analyses, allowing structural tissue changes to be evaluated alongside systemic metabolic parameters.

2.12. Statistical Analysis

The experimental data were expressed as mean $\pm$ standard deviation (SD). Statistical comparisons among the four experimental groups were performed using one-way analysis of variance (ANOVA). When the ANOVA indicated a statistically significant difference, a suitable post hoc multiple-comparison procedure was applied. Where Duncan's multiple range test was used for comparison of group means, the procedure was conducted according to the method described by Duncan (1955). Differences were considered statistically significant at $p < 0.05$.

2.13. Ethical Considerations

All experimental procedures involving animals were reviewed and approved by the Institutional Research Ethics Committee of Al-Baha University, Saudi Arabia (Approval No. 47119677; dated 17 May 2026). The study was conducted in accordance with the approved animal-care protocol and applicable principles for the humane care and use of laboratory animals. Appropriate measures were taken throughout the study to minimize animal stress, discomfort, and unnecessary suffering (Percie du Sert et al., 2020).

3. RESULTS

3.1 . Nutritional and phytochemical composition of baobab fruit powder

The nutritional and phytochemical composition of baobab fruit powder, expressed on a dry-weight basis, revealed a heterogeneous profile of macronutrients and bioactive compounds. The powder contained 2.45 ± 0.04 g/100 g of crude protein and 1.14 ± 0.02 g/100 g of crude fat. The crude fiber content was 6.78 ± 0.19 g/100 g, while the ash content reached 12.85 ± 0.11 g/100 g. Total carbohydrates represented the major nutritional fraction, with a content of 72.40 ± 0.85 g/100 g DW. In addition to its nutritional constituents, baobab fruit powder exhibited a considerable concentration of phenolic and flavonoid compounds.

The total phenolic content (TPC) was 3420.8 ± 210.5 mg GAE/100 g DW, expressed as gallic acid equivalents, whereas the total flavonoid content (TFC) was 415.6 ± 32.4 mg QE/100 g DW, expressed as quercetin equivalents. Collectively, these values indicate that baobab fruit powder contains substantial levels of phenolic and flavonoid compounds alongside its nutritional constituents. However, the reported values should be considered indicative, as the chemical composition of baobab fruit may vary according to factors such as geographical origin, fruit maturity, post-harvest handling, processing conditions, and the analytical methods employed.

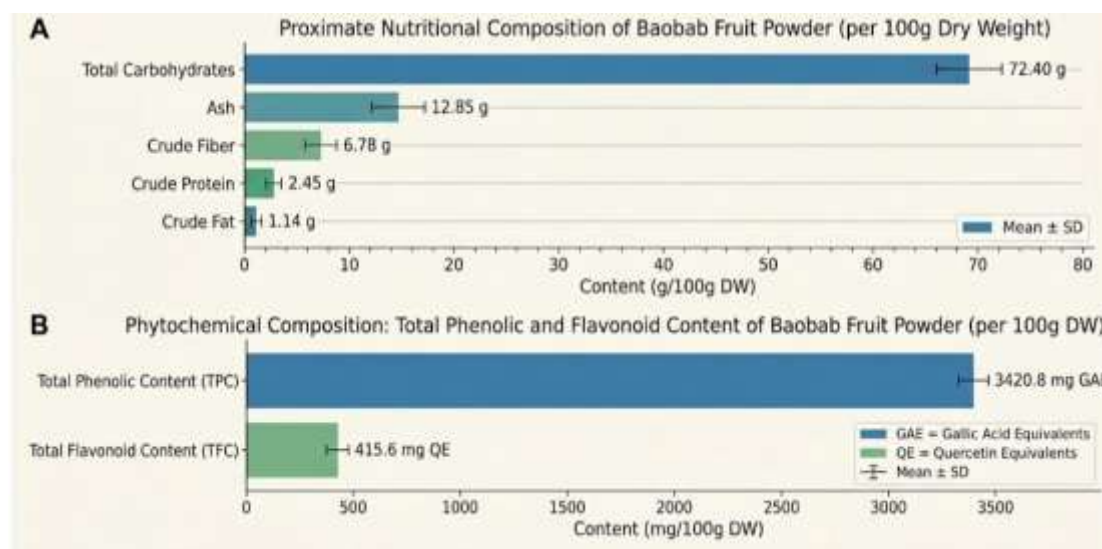


Figure 2: Indicative proximate nutritional and phytochemical composition of baobab fruit powder. Panel (A) illustrates the proximate nutritional composition (crude protein, crude fat, crude fiber, ash, and total carbohydrates) expressed in g/100 g dry weight (DW). Panel (B) shows the total phenolic content (TPC, expressed as mg gallic acid equivalents [GAE]/100 g DW) and total flavonoid content (TFC, expressed as mg quercetin equivalents [QE]/100 g DW). Values are presented as mean $\pm$ standard deviation (SD).

3.2. Biological evaluation

The effects of baobab fruit powder supplementation on body weight and food intake are presented in **Figure 3**. The initial body weights of the experimental animals ranged from 168.40 ± 8.58 to 182.10 ± 8.70 g, with significant differences observed among the experimental groups ($p < 0.05$). At the end of the experimental period, the positive control group (G2) exhibited

the highest final body weight (358.90 ± 24.56 g), whereas the negative control group (G1) recorded the lowest value (291.60 ± 15.43 g). The groups supplemented with 5% and 7% baobab fruit powder (G3 and G4, respectively) showed final body weights of 328.70 ± 12.35 and 305.20 ± 11.28 g, respectively.

A similar pattern was observed for body weight gain. The highest body weight gain was recorded in G2 (176.80 ± 12.35 g), while G1 showed the lowest gain (123.20 ± 10.24 g). Supplementation with baobab fruit powder resulted in body weight gains of 157.50 ± 28.61 g and 130.60 ± 10.64 g in G3 and G4, respectively. Significant differences were observed among the experimental groups ($p < 0.05$), as indicated by the different superscript letters.

Regarding food intake, G2 recorded the highest total food intake (512.40 ± 28.61 g), followed by G3 (450.10 ± 7.49 g) and G4 (432.50 ± 32.17 g), whereas the lowest intake was observed in G1 (410.20 ± 25.16 g). The actual daily food intake followed a comparable pattern, with values of 12.15 ± 0.05 , 10.50 ± 0.05 , 10.25 ± 0.08 , and 9.80 ± 0.04 g/day for G2, G3, G4, and G1, respectively. Overall, the data demonstrate significant differences in body weight parameters and food intake among the experimental groups, with the magnitude of these changes varying according to the dietary treatment.

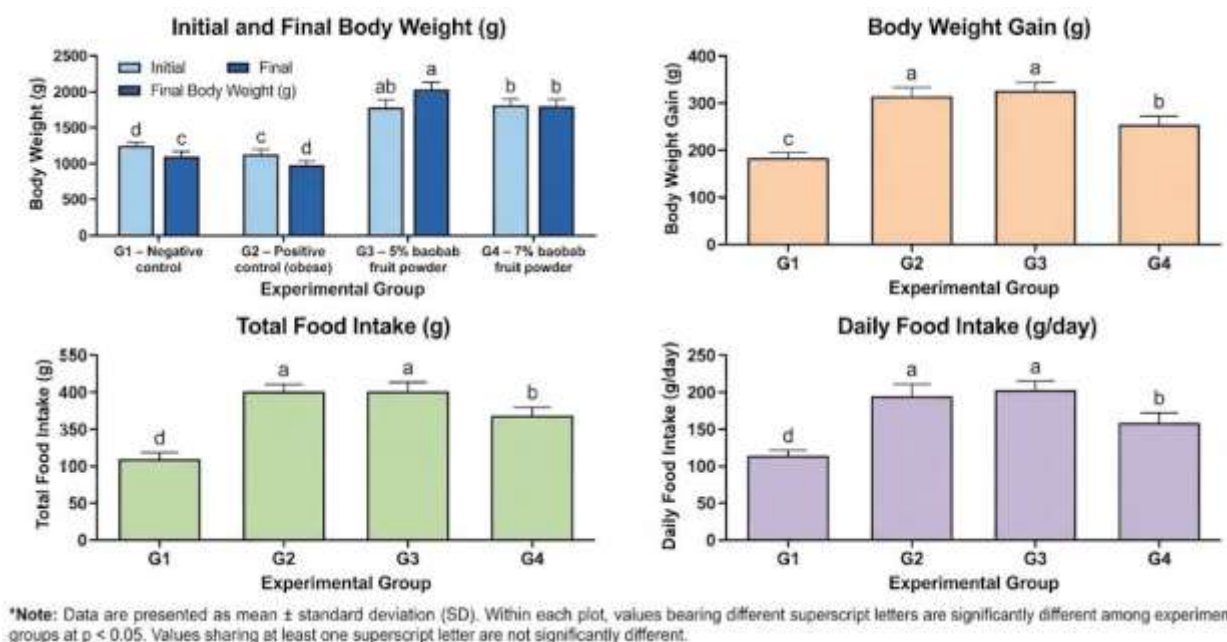


Figure 3. Effects of baobab fruit powder supplementation on body weight and food intake in experimental animals. Data are expressed as mean $\pm$ standard deviation (SD). Different superscript letters (a–d) indicate statistically significant differences among groups within the same parameter ($p < 0.05$), whereas values sharing a common superscript letter do not differ significantly.

3.3. Biochemical Analysis

• Serum Lipid Profile

The serum lipid profile of the experimental rats is presented in Figure 4. The obese positive control group (G2) exhibited a marked alteration in serum lipid parameters compared with the negative control group (G1). Serum triglyceride and total cholesterol concentrations were significantly higher in G2, reaching 238.4 ± 16.2 and 184.6 ± 15.2 mg/dL, respectively, compared with 108.5 ± 5.8 and 82.4 ± 10.5 mg/dL in G1 ($p < 0.05$). In contrast, the HDL-C concentration was significantly lower in the obese positive control group (25.1 ± 3.0 mg/dL) than in the negative control group (56.2 ± 3.9 mg/dL). Similarly, LDL-C increased substantially in G2, reaching 126.5 ± 9.4 mg/dL compared with 22.8 ± 2.34 mg/dL in G1.

Dietary supplementation with baobab fruit powder produced changes in the serum lipid profile of the obese rats. Rats receiving 5% baobab fruit powder (G3) showed lower triglyceride and total cholesterol concentrations than the obese positive control group, with values of 174.2 ± 9.5 and 139.8 ± 15.8 mg/dL, respectively. The 7% supplementation group (G4)

exhibited further reductions in these parameters, recording 144.6 ± 11.5 mg/dL for triglycerides and 118.2 ± 9.6 mg/dL for total cholesterol. Both baobab-supplemented groups also showed higher HDL-C concentrations than the obese positive control group, with values of 36.5 ± 2.6 mg/dL in G3 and 43.8 ± 2.1 mg/dL in G4.

A reduction in LDL-C was also observed following baobab supplementation. The LDL-C concentration decreased from 126.5 ± 9.4 mg/dL in the obese positive control group to 74.2 ± 7.5 mg/dL in G3 and 41.6 ± 3.82 mg/dL in G4. According to the superscript lettering, significant differences among groups were observed within each lipid parameter ($p < 0.05$). Overall, baobab fruit powder supplementation was associated with changes in the serum lipid profile, including lower triglyceride, total cholesterol, and LDL-C concentrations and higher HDL-C concentrations compared with the untreated obese control group.

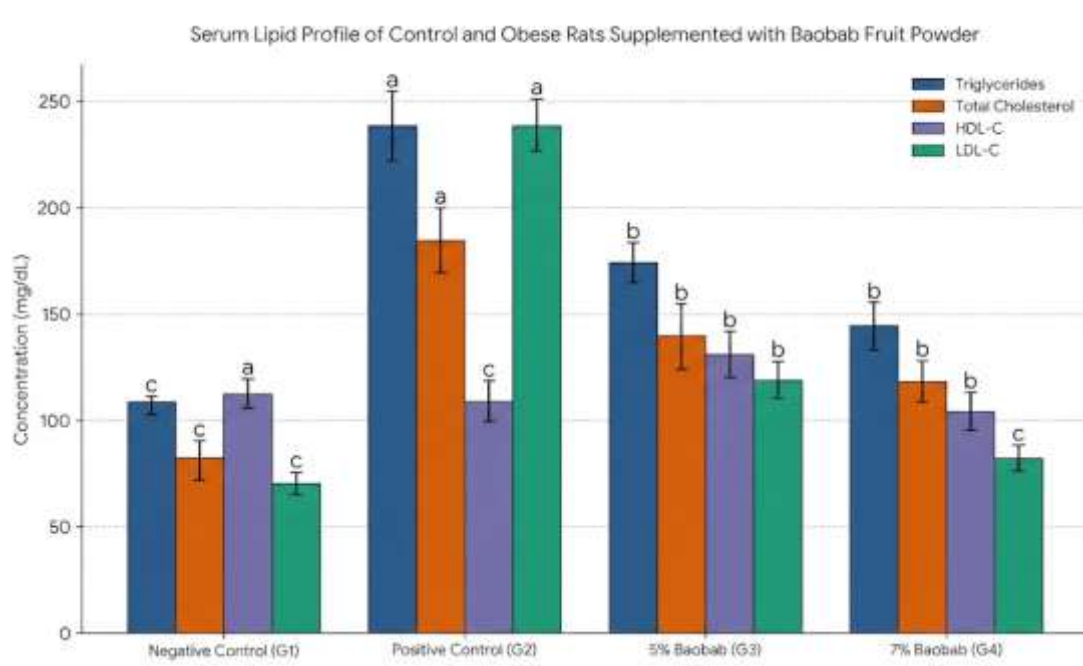


Figure 4. Serum lipid profile, including triglycerides, total cholesterol, HDL-C, and LDL-C, in control and obese rats receiving diets supplemented with different levels of baobab (*Adansonia digitata* L.) fruit powder. Data are expressed as mean $\pm$ standard deviation (SD) ($n = 6$). Within each parameter, bars bearing different superscript letters (a–c) indicate statistically significant differences among the experimental groups ($p < 0.05$). Abbreviations: HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

• Liver Function

The effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder on selected liver function biomarkers in high-fat diet-induced obese rats are presented in **Figure 6**. The positive control group (G2) showed significantly higher serum activities of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP) than the negative control group (G1) ($p < 0.05$). ALT activity increased from 18.5 ± 0.95 U/L in G1 to 52.4 ± 2.45 U/L in G2, while AST activity increased from 7.4 ± 0.88 to 14.2 ± 0.90 U/L. Similarly, ALP activity increased from 32.8 ± 3.12 U/L in the negative control group to 61.5 ± 3.90 U/L in the obese positive control group.

Dietary supplementation with baobab fruit powder was associated with a reduction in the measured liver enzyme activities compared with the obese positive control group. In rats receiving 5% baobab fruit powder (G3), ALT activity was 46.8 ± 0.85 U/L, whereas AST and ALP activities were 12.1 ± 0.92 and 49.6 ± 4.20 U/L, respectively. Increasing the supplementation level to 7% (G4) resulted in further reductions in all three biomarkers, with ALT, AST, and ALP activities reaching 33.2 ± 0.84 , 9.8 ± 1.05 , and 37.5 ± 4.80 U/L, respectively.

According to the statistical comparisons, significant differences among the experimental groups were observed for the assessed liver biomarkers ($p < 0.05$). The 7% baobab-supplemented group showed enzyme activities closer to those observed in the negative control group, particularly for ALP. These findings indicate that dietary supplementation with baobab fruit powder was associated with changes in serum liver enzyme activities in high-fat diet-induced obese rats, with the magnitude of the observed changes varying according to the supplementation level.

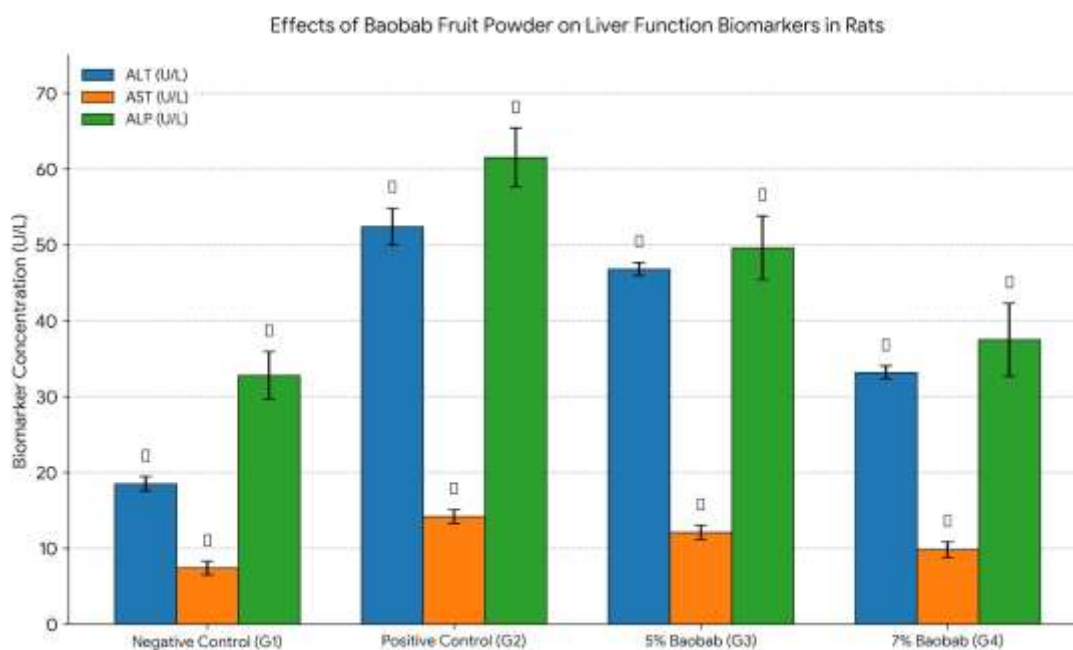


Figure 5. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder on serum liver function biomarkers in high-fat diet-induced obese rats.

• Renal Function Biomarkers

The effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder on selected renal function biomarkers in high-fat diet-induced obese rats are presented in **Figure 6**. The obese positive control group (G2) exhibited significantly higher serum concentrations of urea, creatinine, uric acid, and bilirubin than the negative control group (G1) ($p < 0.05$). Urea concentration increased from 24.8 ± 4.1 mg/dL in G1 to 59.4 ± 0.9 mg/dL in G2, while creatinine increased from 0.46 ± 0.09 to 0.76 ± 0.18 mg/dL. Similarly, uric acid and bilirubin concentrations increased from 2.80 ± 0.22 and 0.28 ± 0.01 mg/dL in G1 to 5.35 ± 0.19 and 0.43 ± 0.04 mg/dL in G2, respectively.

Dietary supplementation with baobab fruit powder was associated with lower values of the assessed biomarkers compared with the obese positive control group. In rats receiving 5% baobab fruit powder (G3), serum urea, creatinine, uric acid, and bilirubin concentrations were 33.1 ± 4.9 , 0.65 ± 0.09 , 4.12 ± 0.22 , and 0.41 ± 0.03 mg/dL, respectively. Increasing the supplementation level to 7% (G4) resulted in further reductions in urea and creatinine concentrations, which reached 29.8 ± 2.05 and 0.58 ± 0.09 mg/dL, respectively. Uric acid and bilirubin concentrations in G4 were 3.38 ± 0.32 and 0.33 ± 0.02 mg/dL, respectively.

The statistical analysis revealed significant differences among the experimental groups for the evaluated renal function biomarkers ($p < 0.05$). According to the superscript lettering, the 7% baobab-supplemented group (G4) did not differ significantly from the negative control group (G1) in uric acid and bilirubin concentrations. For urea and creatinine, G3 and G4 shared the same superscript letter, indicating no significant difference between the two supplementation levels for these parameters. Overall, baobab fruit powder supplementation was associated with changes in serum renal function biomarkers in high-fat diet-induced obese rats, with the observed responses varying according to the supplementation level.

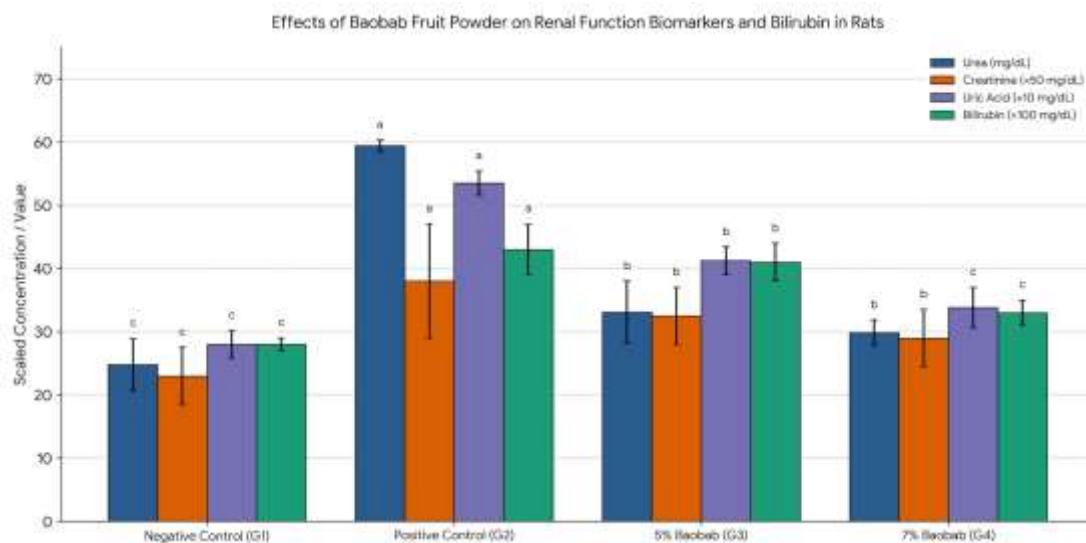


Figure 6. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder on serum renal function biomarkers in high-fat diet-induced obese rats.

- **blood glucose and pancreatic enzyme activities**

The effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder on blood glucose concentration and pancreatic enzyme activities in high-fat diet-induced obese rats are presented in **Figure 7**. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder on blood glucose concentration and pancreatic enzyme activities in high-fat diet-induced obese rats.

The positive control group (G2) exhibited a significantly higher blood glucose concentration than the negative control group (G1), with values of 172.8 ± 3.5 and 112.4 ± 5.2 mg/dL, respectively ($p < 0.05$). Rats receiving 5% baobab fruit powder (G3) showed a lower blood glucose concentration of 154.6 ± 4.9 mg/dL, whereas the 7% supplementation group (G4) recorded a value of 135.2 ± 5.3 mg/dL. According to the statistical grouping, G3 and G4 did not differ significantly from each other, although both groups showed lower blood glucose concentrations than the positive control group. A marked alteration in amylase activity was observed among the experimental groups. The positive control group recorded the highest amylase activity (3250 ± 128.5 U/L), which was significantly greater than that observed in the negative control group (965 ± 98.5 U/L) ($p < 0.05$). Dietary supplementation with 5% baobab fruit powder reduced amylase activity to 2680 ± 155.2 U/L, while increasing the supplementation level to 7% resulted in a further decrease to 1750 ± 172.0 U/L. The 7% supplementation group did not differ significantly from the negative control group, whereas the 5% supplementation group showed an intermediate response according to the superscript lettering. In contrast, lipase activity did not differ significantly among the experimental groups ($p > 0.05$). The recorded values ranged from 75.20 ± 2.30 U/L in the negative control group to 85.40 ± 2.80 U/L in the positive control group. Rats receiving 5% and 7% baobab fruit powder exhibited lipase activities of 78.10 ± 3.90 and 76.25 ± 4.20 U/L, respectively. Because all groups shared the same superscript letter, these numerical differences were not statistically significant. Overall, dietary supplementation with baobab fruit powder was associated with lower blood glucose concentrations and reduced amylase activity in high-fat diet-induced obese rats, particularly at the 7% supplementation level, whereas lipase activity remained statistically unchanged among the experimental groups.

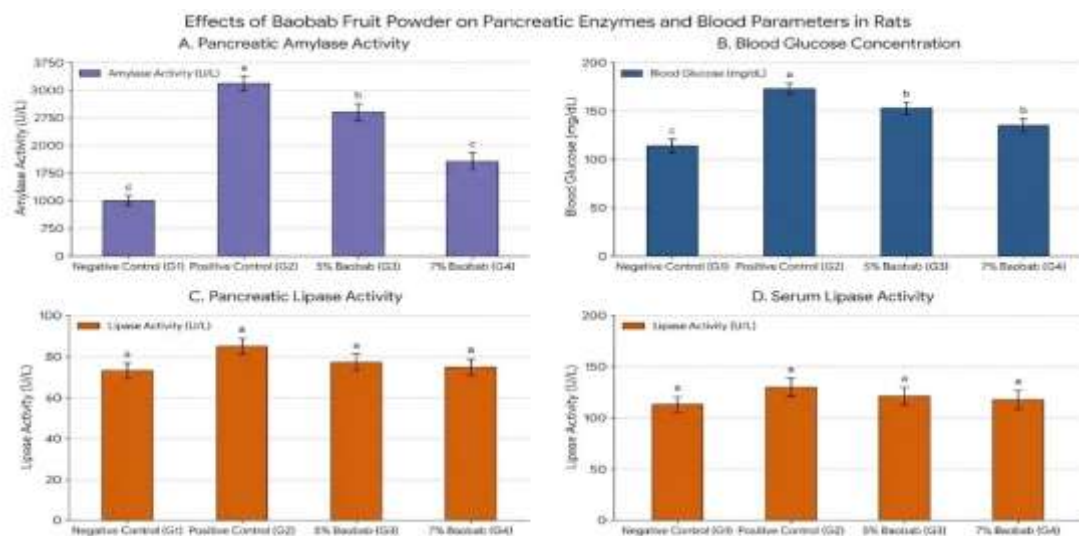


Figure 7. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder on blood glucose concentration and pancreatic enzyme activities in high-fat diet-induced obese rats.

3.3. Histopathological Examination of Cardiac Tissue (H&E Staining, ×400)

Histopathological examination of cardiac tissue sections stained with hematoxylin and eosin (H&E) at ×400 magnification demonstrated marked attenuation of high-fat diet-induced myocardial alterations following dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder.

Group 1 (Negative Control): Cardiac sections exhibited normal myocardial architecture, characterized by regularly arranged, striated cardiac myocytes with centrally located nuclei and preserved interstitial spaces. No apparent histopathological abnormalities were observed.

Group 2 (Positive Control – High-Fat Diet/Obese Model): Cardiac sections from the untreated obese rats showed evident histopathological alterations, including focal infiltration of mononuclear inflammatory cells between cardiac myocytes, vascular congestion, and areas of myofibrillar degeneration.

Group 3 (Treatment – 5% Baobab Fruit Powder): Dietary supplementation with 5% baobab fruit powder resulted in a noticeable improvement in the cardiac histological architecture. The sections showed mild intermuscular edema, with relatively preserved myocardial structure and reduced inflammatory cell infiltration compared with the positive control group.

Group 4 (Treatment – 7% Baobab Fruit Powder): Rats receiving 7% baobab fruit powder demonstrated a greater degree of histological preservation. The myocardial architecture was well maintained, with regularly arranged cardiac myocytes and no apparent histopathological lesions or inflammatory cell infiltration, resembling the findings observed in the negative control group. The histopathological findings support the potential cardioprotective effect of *Adansonia digitata* fruit powder against high-fat diet-associated myocardial alterations, with the most pronounced histological preservation observed at the 7% supplementation level. These effects may be associated with the bioactive constituents of baobab fruit, including polyphenols, flavonoids, and organic acids, which have been reported to possess antioxidant and anti-inflammatory properties. However, the proposed mechanisms should be interpreted cautiously and supported by corresponding biochemical, molecular, or oxidative-stress biomarkers.

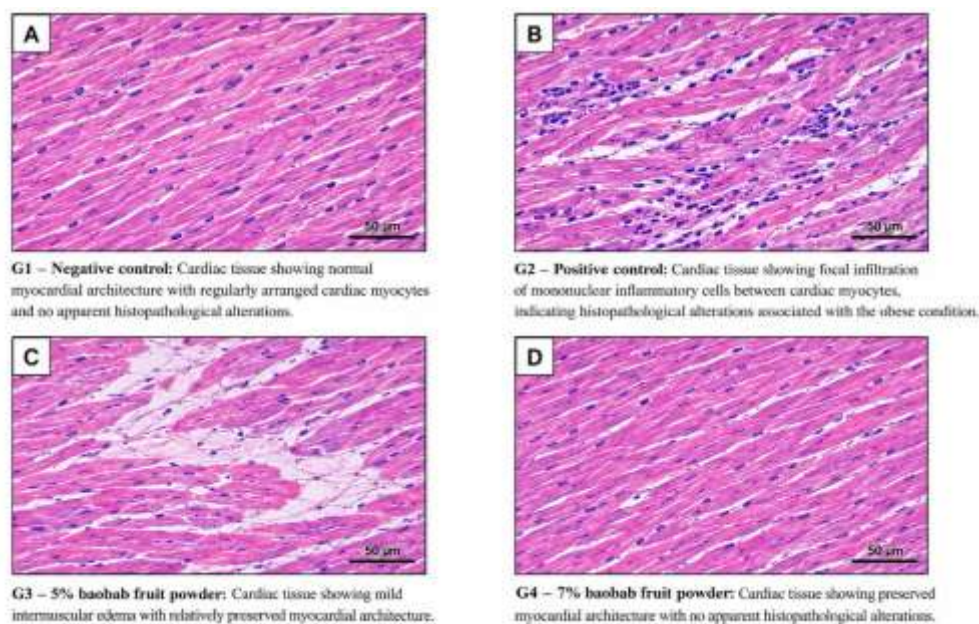


Figure 8. Representative photomicrographs of cardiac tissue from the experimental rats (H&E staining, ×400). G1, negative control group; G2, positive control group (high-fat diet-induced obese rats); G3, rats receiving 5% baobab (*Adansonia digitata* L.) fruit powder; G4, rats receiving 7% baobab fruit powder.

4- DISCUSSION

Obesity is a multifactorial metabolic disorder associated with disturbances in lipid and glucose metabolism and with adverse effects on several organs, including the liver, kidneys, and cardiovascular system. Dietary models of obesity, particularly high-fat diet (HFD)-induced models, are widely used to reproduce several metabolic abnormalities associated with obesity and to evaluate potential nutritional interventions (de Moura e Dias et al., 2021). In the present study, dietary supplementation with whole dried baobab (*Adansonia digitata* L.) fruit powder was associated with improvements in several metabolic and biochemical parameters in HFD-fed rats. These effects were observed across body-weight gain, serum lipid profile, blood glucose, pancreatic enzyme activity, liver-related biomarkers, renal and hepatobiliary biomarkers, and cardiac histopathology. The magnitude of several changes was numerically greater in rats receiving 7% baobab powder than in those receiving 5%, although the present study was not designed to establish a formal dose–response relationship.

Nutritional and phytochemical characteristics of baobab fruit

The potential biological effects of baobab fruit may be related to its complex nutritional and phytochemical composition. Baobab fruit contains dietary fiber and several classes of bioactive compounds, including phenolic acids, flavonoids, proanthocyanidins, and other secondary metabolites. Comprehensive metabolomic investigations of *A. digitata* fruit have identified sugars, amino acids, organic acids, phenolic compounds, fatty acids, triacylglycerols, sterols, and other metabolites, indicating the considerable chemical complexity of the fruit (Sokeng et al., 2019). Similarly, Ismail et al. (2019) identified numerous phytochemicals in baobab fruit pulp, including proanthocyanidins, phenolic acids, flavonols, and saponins, while Braca et al. (2018) reported procyanidins and flavonol glycosides among the major phenolic constituents of baobab fruit. These compositional characteristics provide a plausible nutritional basis for the metabolic effects observed in the present study. However, because the current intervention used whole dried fruit powder rather than a purified extract or isolated compound, the observed effects should not be attributed to a single phytochemical constituent. Moreover, the contribution of individual compounds and their possible interactions cannot be determined from the present experimental design.

Effects on body weight and food intake

The reduction in body-weight gain observed following baobab supplementation suggests a potential beneficial effect on weight regulation in HFD-fed rats. Compared with the obese control group, body-weight gain was reduced by approximately

10.9% and 26.1% in the 5% and 7% baobab groups, respectively. The greater numerical reduction in the 7% group may indicate a concentration-related effect; however, a formal dose–response relationship cannot be established from only two concentrations. One possible explanation for the reduction in body-weight gain is the relatively high dietary fiber content of baobab fruit. Dietary fiber may influence satiety, gastrointestinal transit, nutrient absorption, and energy availability. In addition, the phytochemical constituents of baobab may contribute to metabolic regulation. Nevertheless, these mechanisms were not directly assessed in the present study, and therefore they should be regarded as possible explanations rather than demonstrated mechanisms. The present findings are broadly consistent with previous animal studies. Elamin and Abdel Atti (2019) reported reductions in body weight and serum lipid parameters in rats receiving baobab pulp powder with high-lipid diets. Similarly, Suliman et al. (2020) observed beneficial metabolic effects following administration of baobab fruit pulp to rats exposed to a high-sugar/high-fat dietary model. Although these studies used dietary models that differ from the present HFD protocol, their findings provide supporting evidence for the potential of baobab fruit to influence metabolic abnormalities associated with energy-dense diets.

Effects on serum lipid profile

Baobab supplementation was associated with substantial improvements in the serum lipid profile. Compared with the obese control group, triglyceride concentrations decreased by approximately 26.9% and 39.3% in the 5% and 7% groups, respectively. Total cholesterol decreased by approximately 24.3% and 36.0%, while LDL-C decreased by approximately 41.3% and 67.1%, respectively. In parallel, HDL-C increased from 25.1 mg/dL in the obese control group to 36.5 and 43.8 mg/dL in the 5% and 7% groups. The improvement in these lipid parameters may reflect the combined effects of dietary fiber and bioactive constituents present in baobab fruit. Dietary fiber can modify lipid metabolism through effects on intestinal lipid absorption and bile acid metabolism, whereas polyphenolic compounds may influence pathways involved in lipid synthesis and oxidation. However, these pathways were not directly measured in the present study and should therefore not be considered established mechanisms. The observed lipid improvements are consistent with previous experimental evidence. Elamin and Abdel Atti (2019) reported reductions in triglycerides, total cholesterol, and LDL-C in rats fed high-lipid diets supplemented with baobab pulp powder. Likewise, Suliman et al. (2020) reported favorable changes in LDL-C, triglycerides, and total cholesterol in a high-sugar/high-fat rat model treated with baobab fruit. The consistency among these studies is noteworthy because the interventions involved baobab fruit or pulp rather than isolated compounds, although differences in dietary composition, dose, and experimental duration should be considered when comparing the findings.

Effects on blood glucose and serum amylase activity

Baobab supplementation also improved blood glucose concentrations. Relative to the obese control group, glucose levels were reduced by approximately 10.5% in the 5% group and 21.8% in the 7% group. These findings are consistent with previous evidence suggesting that baobab fruit may influence postprandial glycemic responses. Coe et al. (2013) reported that a polyphenol-rich baobab preparation reduced starch digestion and postprandial glycemic response in humans, while Braca et al. (2018) reported antioxidant and α -glucosidase inhibitory activities in baobab fruit extracts. The reduction in serum glucose observed in the present study may therefore be compatible with previously reported effects of baobab on carbohydrate digestion and glucose metabolism. However, the evidence from Coe et al. (2013) involved acute human responses and baobab preparations rather than the chronic administration of whole fruit powder in an obese rat model. Similarly, the α -glucosidase-related findings reported by Braca et al. (2018) were obtained using extracts and in vitro assays. Accordingly, these studies provide biological plausibility but do not establish the mechanism responsible for the glucose-lowering effect observed in the present experiment. Serum amylase activity was also reduced following baobab supplementation, with decreases of approximately 17.5% and 46.2% in the 5% and 7% groups, respectively, compared with the obese control group. Although the reduction in serum amylase may indicate an alteration in pancreatic or digestive enzyme activity, serum amylase should not be interpreted as a direct measure of intestinal α -amylase inhibition. Additional investigations measuring digestive enzyme activity directly, together with insulin concentration and indices of insulin resistance, would be required to clarify the basis of the observed glucose-related effects.

Effects on liver-related biomarkers

The present study demonstrated improvements in serum ALT, AST, and ALP following baobab supplementation, particularly at the 7% concentration. Compared with the obese control group, ALT, AST, and ALP decreased by approximately 36.6%,

31.0%, and 39.0%, respectively, in the 7% group. Because elevations in these enzymes may accompany hepatic injury or metabolic disturbances associated with obesity, their reduction may suggest attenuation of liver-associated biochemical abnormalities. Previous experimental evidence provides some support for a hepatoprotective potential of baobab preparations. Makena et al. (2021) reported reductions in ALT, AST, and ALP and improvements in hepatic histology following administration of an aqueous baobab fruit-pulp extract in rats exposed to lead acetate. However, the experimental injury in that study was chemically induced and therefore differs substantially from HFD-induced metabolic stress. Consequently, the findings should be considered supportive evidence for possible organ-protective properties rather than direct confirmation of the mechanism underlying the present results.

It is also important to distinguish between serum biochemical markers and comprehensive assessment of liver function. The observed reductions in ALT, AST, and ALP indicate improvement in these circulating biomarkers but do not by themselves establish complete restoration of hepatic function or demonstrate the absence of hepatic steatosis. Histological assessment of the liver and measurement of additional metabolic, inflammatory, and oxidative-stress markers would provide a more comprehensive evaluation.

Effects on renal and hepatobiliary biomarkers

Baobab supplementation was also associated with improvements in renal and hepatobiliary-related biochemical parameters. In the 7% group, urea, creatinine, and uric acid were reduced by approximately 49.8%, 23.7%, and 36.8%, respectively, compared with the obese control group. These changes may indicate attenuation of biochemical abnormalities associated with the HFD condition. The findings are partly consistent with the study of Makena et al. (2021), in which baobab fruit-pulp extract reduced serum urea and creatinine and improved renal histological features in rats subjected to lead-acetate-induced toxicity. Nevertheless, the toxicant-induced model used in that study is different from the metabolic stress associated with HFD-induced obesity. Thus, the present findings should be interpreted as evidence of an association between baobab supplementation and improved renal biochemical markers rather than definitive evidence of a specific nephroprotective mechanism. Similarly, changes in bilirubin and related hepatobiliary biomarkers may reflect improvement in biochemical disturbances associated with the experimental diet. However, biochemical measurements alone cannot fully characterize renal function or hepatobiliary status. Future studies incorporating histopathological examination of the kidneys and liver, together with additional functional and molecular markers, would strengthen the interpretation of these findings.

Cardiac histopathological findings

The histopathological findings provide additional evidence of a potential beneficial association between baobab supplementation and cardiac tissue integrity in HFD-fed rats. The obese control animals exhibited histological alterations consistent with cardiac injury, whereas baobab-treated groups showed improved myocardial morphology, with the 7% group demonstrating more pronounced apparent improvement. Cardiac alterations associated with high-fat feeding have been documented experimentally. Cardoso et al. (2023), for example, demonstrated that a high-fat diet can induce cardiac damage and metabolic disturbances even in obesity-resistant rodents. These findings support the concept that dietary lipid excess may adversely affect cardiac tissue independently of the extent of body-weight gain. However, because the cardiac histopathology in the present study was evaluated qualitatively, the apparent improvement should be interpreted cautiously. Quantitative histological scoring and assessment of cardiac biochemical or molecular markers would be necessary to establish the magnitude and mechanism of cardiac protection. Previous work has also suggested potential cardioprotective properties of *A. digitata*. Ghoneim et al. (2016) reported protective effects of *A. digitata* against isoproterenol-induced myocardial injury in rats. Although this finding is relevant to the possibility of cardioprotective activity, the isoproterenol model represents acute chemically induced myocardial injury and is not equivalent to HFD-induced metabolic cardiac damage. Therefore, the present findings extend the existing evidence in a different experimental context but do not establish a common mechanism.

Possible mechanisms underlying the observed effects

Several mechanisms may potentially contribute to the improvements observed following whole baobab fruit-powder supplementation. First, dietary fiber may influence satiety, gastrointestinal transit, nutrient absorption, and lipid metabolism. Second, phenolic compounds and flavonoids present in baobab may contribute to antioxidant and metabolic effects. Baobab fruit has been shown to contain a diverse range of phenolic compounds and other metabolites with biological activity (Sokeng

et al., 2019; Ismail et al., 2019; Braca et al., 2018). Third, previous studies have reported effects of baobab preparations on carbohydrate digestion and glycemic responses (Coe et al., 2013). Nevertheless, the current study did not directly measure oxidative stress, inflammatory mediators, insulin resistance, gene expression, or specific metabolic signaling pathways. Therefore, antioxidant, anti-inflammatory, insulin-sensitizing, or lipid-regulating mechanisms should be regarded as hypotheses supported by previous evidence rather than mechanisms demonstrated by the present experiment. This distinction is particularly important because the biological activity of whole fruit powder may differ from that of solvent-derived extracts or purified phytochemicals.

Comparison with previous evidence and study significance

Overall, the present findings are broadly consistent with the growing preclinical literature suggesting that baobab fruit may have favorable metabolic effects. Animal studies have reported improvements in lipid and glucose-related parameters following baobab supplementation in dietary or chemically induced models (Elamin & Abdel Atti, 2019; Suliman et al., 2020; Makena et al., 2021). Chemical and metabolomic investigations have further demonstrated that baobab fruit contains a complex mixture of potentially bioactive constituents (Sokeng et al., 2019; Ismail et al., 2019).

An important feature of the present study is the use of whole dried baobab fruit powder rather than a purified extract. This approach is nutritionally relevant because the effects of whole fruit may result from the combined contribution of fiber, nutrients, and multiple phytochemicals. However, it also makes it difficult to attribute the observed effects to individual compounds or pathways. Furthermore, the relatively short intervention period and the use of an animal model limit direct extrapolation to long-term human dietary use. Human evidence concerning baobab fruit powder and cardiometabolic health remains comparatively limited. Riedel et al. (2025) described a randomized placebo-controlled trial protocol investigating the effects of baobab fruit powder in adults with obesity, including cardiometabolic and safety-related outcomes. Importantly, this publication is a study protocol rather than a report of completed clinical outcomes. Therefore, it demonstrates ongoing interest in translating preclinical findings into human research but cannot be used as evidence of clinical efficacy.

5. CONCLUSION

The present study demonstrates that dietary supplementation with whole baobab (*Adansonia digitata* L.) fruit powder was associated with favorable metabolic and biochemical changes in high-fat diet-induced obese rats. Baobab supplementation, particularly at 7%, was associated with reduced body-weight gain, improved serum lipid and glucose profiles, and favorable changes in liver- and kidney-related biochemical markers. The improvement in cardiac histological appearance further supports a potential protective effect against obesity-associated tissue alterations. These effects may be related to the combined nutritional and phytochemical properties of baobab fruit, including its dietary fiber, phenolic compounds, flavonoids, and other bioactive constituents. Overall, the findings suggest that whole baobab fruit powder may have potential as a functional dietary ingredient for mitigating metabolic disturbances associated with obesity. However, the results should be interpreted within the limitations of the animal model and the relatively short intervention period. Further studies incorporating quantitative histopathological assessment, oxidative-stress and inflammatory biomarkers, insulin-resistance indices, and longer-term interventions are warranted to clarify the underlying mechanisms and determine the translational relevance of these findings to human nutrition.

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